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Oak Ridge National Laboratory, Tennessee

November 1976

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The interaction of electrons with the solids Ge and GaAs is described based on a model insulator theory for the valence band electrons and inner shell ionization derived from classical-binary-collision cross sections. Contributions to the inverse mean free path and stopping power from the various interaction processes are tabulated for electron energies from threshold (~2 eV for Ge and ~2.5 eV for GaAs) to 10 keV. Electron range in the continuous slowing-down approximation and straggling are tabulated for electron energies from 10 eV to 10 keV for both materials.

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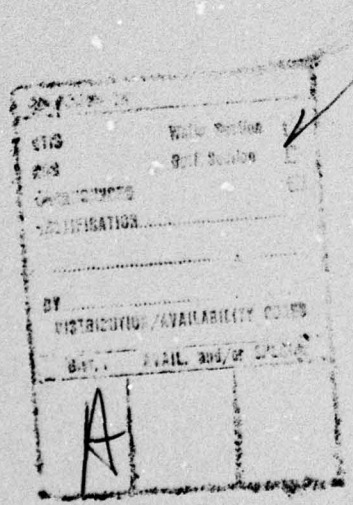

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I. INTRODUCTION

A quantitative description of the interaction of electrons with matter over a large range of energies is a subject of basic importance in a wide variety of theoretical and applied areas. From the theoretical standpoint, calculations of energy loss and range of electrons in many different materials have formed the basis of at least two extensive tabulations.[1,2] Both of these works are restricted to electron energies $\geq$ 10 keV and are based on the Bethe theory of stopping power including various modifications and corrections (e.g., density-effect corrections). We feel that similar tabulations for electron energies $\leq$ 10 keV, based on a priori calculations using currently available theoretical information, will provide useful guides for interpretation of experimental data as well as input for calculations in applied areas. Our earlier tabulations for the electron energy region E$\leq$10 keV include the solids Al and Al_2O_3][3], Si and SiO_2][4], and Ni, Cu, Ag, and Au][5]. Although some of the theoretical framework required for the calculations presented here for Ge and GaAs is identical to that in Refs. 3 and 4, it will be restated here for convenience of the users of this tabulation.

Model calculations are used in the work here to describe the valence bands of the solids. The differential inverse mean free path (DIMFP), which forms the basic function required in our work, will be derived from a model insulator theory[3,4] applied to the valence bands in Ge and GaAs. The more tightly bound, inner shells of the atoms in the solids will be assumed to be essentially unchanged in

character from those in free atoms and the DIMFP for excitation of electrons from the inner shells will be based on classical binary collision (CBC) theory.[6,7,8] An extension of CBC theory in which the cross sections are constrained to obey certain sum rules has been applied in the study of the electron slowing-down spectrum in Si.[9] Given the DIMFP's associated with the most important electron interaction processes in the solids, we then calculate inverse mean free paths, stopping powers, csda ranges, and range and energy straggling for electron energies from a few eV to 10 keV.

The details of the components of our calculations are described more fully in the next three sections. In Section V exchange corrections are discussed, expressions given for the exchange corrected DIMFP's, and formulas used in these tabulations are displayed.

II. GENERAL FORMULATIONS

A charged particle passing through a solid interacts with a large number of electrons simultaneously, and it is thus appropriate to speak of a mean free path of the charged particle against energy loss to the solid. Assuming the effect of the charged particle on the medium may be treated in first Born approximation, the inverse mean free path, differential in momentum transfer, $\hbar\vec{k}$, and energy transfer, $\hbar\omega$, for a particle of velocity v is given by

$$\frac{d^2\mu}{dk\,d\omega} = \frac{2e^2}{\pi\hbar v^2}\,\frac{1}{k}\,\mathrm{Im}\left[\frac{-1}{\epsilon(k,\omega)}\right] \qquad (1)$$

where $\epsilon(k,\omega)$ is the exact dielectric function of the solid.[10] We assume in this work that the solid is isotropic and homogeneous.

For our calculations of inverse mean free path, stopping power, etc., it is sufficient to compute inverse mean free paths differential in energy transfer only. This differential inverse mean free path (DIMFP) for energy loss $\hbar\omega$ by an electron with energy $E = mv^2/2$ in the solid is given by

$$\tau(E,\hbar\omega) \equiv \frac{d\mu}{d(\hbar\omega)} = \frac{1}{\pi a_o E}\int_{k_-}^{k_+}\frac{dk}{k}\ \mathrm{Im}\left[\frac{-1}{\epsilon(k,\omega)}\right] \qquad (2)$$

where $\hbar k_{\pm} \equiv \sqrt{2m}\left[\sqrt{E} \pm \sqrt{E-\hbar\omega}\right]$ and $a_o \equiv \hbar^2/me^2$. This expression assumes that the energy-momentum relation for a swift electron in the solid does not differ appreciably from that of a free electron in vacuum.

Given $\epsilon(k,\omega)$ for the solid, the quantities of interest here follow directly from $\tau(E,\hbar\omega)$. The inverse mean free path of the electron, μ, is given by integrating over allowed energy transfers as

$$\mu(E) = \int d(\hbar\omega)\ \tau(E,\hbar\omega)\ . \qquad (3)$$

The rate of energy loss of the electron, or the stopping power of the medium, is given by

$$S(E) \equiv -dE/dx = \int d(\hbar\omega)\ \hbar\omega\ \tau(E,\hbar\omega)\ , \qquad (4)$$

and the mean square energy loss per unit path length by

$$\Omega^2(E) \equiv \int d(\hbar\omega)(\hbar\omega)^2 \tau(E,\hbar\omega) . \tag{5}$$

With these results we may calculate the range of an electron in the continuous slowing-down approximation (csda range) by

$$R_o(E) = \int_{E_o}^{E} dE'/S(E') \tag{6}$$

The lower limit on this integration will be discussed further in Section V. The mean square fluctuation in the range or "range straggling" will be calculated from Eq. (5) and Eq. (4) as[11]

$$(R - R_o)^2_{AV} \equiv \int_{E_o}^{E} dE' \, \Omega^2(E')/[S(E')]^3 . \tag{7}$$

In practice, the DIMFP will be evaluated as a sum of contributions from various distinct processes. For example, we calculate a DIMFP for removing an electron from inner shells and a DIMFP for interaction with electrons in valence bands. The total DIMFP used to describe the interaction of an electron with the given solid will be given by

$$\tau(E,\omega) = \sum_i \tau_i(E,\omega) \tag{8}$$

where the sum over i adds the contributions from the various interaction processes. The evaluation of the τ_i's for Ge and GaAs is described in the next two sections.

III. DIMFP's FOR VALENCE BAND ELECTRONS

The model which we have developed to describe the dielectric response function of an insulator is related to that employed by Fry[12] in which the ground state wave function of the valence electrons is described in the tight-binding approximation, while excited states are represented by orthogonalized plane waves (OPW). In our use of the model to obtain a dielectric response function we fix the normalization of the OPW excited states by requiring that the sum rule $\int_0^\infty d\omega\ \omega \mathrm{Im}[\epsilon(k,\omega)] = 2\pi^2\ ne^2/m$ be obeyed where n is the density of electrons in the valence band. In addition we assume that the solid is uniform and homogeneous. The dielectric response function corresponding to this model solid is convenient and flexible for use, can be fitted to the optical dielectric function in the limit of very long wavelengths ($k \to 0$), and describes the single-particle properties of excited electrons. The existence of plasma oscillations emerges naturally as one studies the response of the system to longitudinal electric perturbations. We have found quite reasonable results in the application of this model to Al_2O_3 and SiO_2.[3,4,13,14]

Since a detailed discussion of the insulator model is planned for publication,[15] we quote here only the results needed for these

calculations. The result required here is the imaginary part of the dielectric response function for the model insulator given by

$$\mathrm{Im}\left[\epsilon(k,\omega)\right] = \pi n e^2 \Gamma / \hbar\beta k \Lambda \tag{9}$$

where

$$\Gamma \equiv \left\{ \frac{1}{3}\left[\frac{1}{\{\alpha^2+(k-p)^2\}^3} - \frac{1}{\{\alpha^2+(k+p)^2\}^3} \right] \right.$$

$$- \frac{32\alpha^4}{(\alpha^2+p^2)^2(4\alpha^2+k^2)^2}\left[\frac{1}{\alpha^2+(k-p)^2} - \frac{1}{\alpha^2+(k+p)^2} \right] \tag{10}$$

$$\left. + \frac{1024 pk\,\alpha^8}{(\alpha^2+p^2)^4(4\alpha^2+k^2)^4} \right\} \quad ,$$

$$\Lambda \equiv \left[\omega_s + \frac{\hbar\beta}{m}(k^2+\alpha^2) \right]\left[\frac{1}{8\alpha^5} - \frac{32\alpha^3}{(4\alpha^2+k^2)^4} \right] \quad , \tag{11}$$

and

$$p = \left[m(\omega-\omega_s)/\hbar\beta \right]^{1/2} \quad . \tag{12}$$

Here $\hbar\omega_\beta$ is the average binding energy of the valence band and β and α are parameters which may be adjusted to make the theory agree with optical dielectric function measurements in the $k \to 0$ limit. In the $k \to 0$ limit we have

$$\mathrm{Im}\left[\epsilon(0,\omega)\right] = \frac{2^9 \pi n e^2}{3\hbar\beta} \frac{\alpha^7}{(\omega_\beta + \frac{\hbar\beta}{m}\alpha^2)} \frac{p^3}{(\alpha^2+p^2)^6} \quad . \tag{13}$$

Given the imaginary part of the dielectric function, Eq. (9), for fixed values of n, β, ω_β, and α the real part of $\epsilon(k,\omega)$ may be obtained numerically using the Kramers-Kronig relation,

$$\mathrm{Re}[\epsilon(k,\omega)] = 1 + \frac{2P}{\pi}\int_0^\infty d\omega_o \frac{\omega_o \,\mathrm{Im}[\epsilon(k,\omega_o)]}{\omega_o^2 - \omega^2} \quad . \tag{14}$$

Equation (13) is used to fit experimental data on $\mathrm{Im}[\epsilon(o,\omega)]$, as obtained from optical measurements or from electron energy loss measurements, to determine parameters for the insulator model. Since the general shape of this function for most semiconductors shows two major peaks separated by a few eV, two terms of the form on the right-hand side of Eq. (13) (corresponding to the combination of two single orbitals in the OPW excited state wave function) were used to provide a reasonable fit to the data.[4] More specifically, the parameters for the tabulations were determined in the following manner:

A. Germanium

For 4 electrons per atom contributing to the valence band, and for a density of 5.30 gm/cm^3 for the solid Ge

an initial set of parameters was determined by fitting the optical data of Ref. 16 to obtain $\mathrm{Im}[\epsilon(o,\omega)]$. From Eq. (14) $\mathrm{Re}[\epsilon(o,\omega)]$ is determined and $\mathrm{Im}[-1/\epsilon(o,\omega)]$ is computed for comparison with the values obtained for this function using energy-loss spectroscopy.[17] Small changes were made in the initial set of parameters so that a good fit was obtained to the measured $\mathrm{Im}[-1/\epsilon(o,\omega)]$. The parameter values obtained in this manner are:

(a) (.9) of the 4 valence electrons: $\hbar\omega_{B_1} = 1.9$ eV, $\alpha_1 a_o = 0.485$, $\beta_1 = 0.5$

(b) (.1) of the 4 valence electrons: $\hbar\omega_{B_2} = 3.9$ eV, $\alpha_2 a_o = 0.19$, $\beta_2 = 0.5$.

Given these values, $\mathrm{Im}[-1/\epsilon(k,\omega)]$ is calculated using Eq. (9) and Eq. (14) to determine the DIMFP for interaction with the valence band electrons. The contribution of this valence band resulting from the combination of these two orbitals will be identified in the tables by VALENCE.

B. Gallium Arsenide

For application of the model insulator theory to GaAs we used experimental data obtained entirely from electron energy loss spectroscopy.[17] As with Ge, an initial set of parameters was obtained from data on $\mathrm{Im}[\epsilon(o,\omega)]$ and the final set of values obtained by requiring a good fit to $\mathrm{Im}[-1/\epsilon(o,\omega)]$. With 8 valence

electrons per molecule and a density of 5.31 gm/cm^3 for solid GaAs, the parameters were determined to be:

(a) (.95) of the 8 valence electrons: $\hbar\omega_{B_1} = 2.45$ eV, $\alpha_1 a_o = 0.53$, $\beta_1 = 0.5$

(b) (.05) of the 8 valence electrons: $\hbar\omega_{B_2} = 4.3$ eV, $\alpha_2 a_o = 0.34$, $\beta_2 = 0.5$.

Given these values, Im $[-1/\epsilon(k,\omega)]$ is calculated using Eq. (9) and Eq. (14) to determine the DIMFP for interaction with valence band electrons. The contribution of this valence band will be identified in the tables by VALENCE.

IV. DIMFP's FOR INNER SHELLS

From a general expression for the dielectric function of a homogeneous, isotropic system[18] we may show for values of ω which correspond to ionization of the i^{th} inner shell in a solid that

$$\mathrm{Im}\left[\frac{-1}{\epsilon(k,\omega)}\right] \approx \mathrm{Im}\,\epsilon(k,\omega) \approx \frac{2\pi n_i e^2}{m\omega}\,\frac{df_i(k,\omega)}{d\omega} \tag{15}$$

where $df_i/d\omega$ is the generalized oscillator strength (GOS) for transistions from the i^{th} level in the atom to a continuum final state. Here n_i is the number of electrons in the i^{th} level per unit volume in the given solid. Equation (2) thus leads to

$$\tau_i\ (E,\hbar\omega) = \frac{2\pi e^4 n_i}{E\hbar\omega}\int_{k_-}^{k_+}\frac{dk}{k}\,\frac{df_i(k,\omega)}{d(\hbar\omega)} \tag{16}$$

where $\hbar\omega$ is the energy transfer. In terms of the doubly-differential cross section per electron for excitation into continuum final states this equation becomes

$$\tau_i (E,\hbar\omega) = n_i \int_{k_-}^{k_+} dk \; \frac{d^2\sigma_i}{dk\,d(\hbar\omega)} \quad , \tag{17}$$

where

$$\frac{d^2\sigma_i}{dk\,d(\hbar\omega)} = \frac{2\pi e^4}{E} \; \frac{1}{k} \; \frac{1}{\hbar\omega} \; \frac{df_i(k,\omega)}{d(\hbar\omega)} \quad . \tag{18}$$

The basic doubly-differential cross section in the classical binary collision (CBC) model is given for spherically symmetric distributions of velocities of the atomic electrons by[6,7]

$$\frac{d^2\sigma_i}{dk\,d(\hbar\omega)} = \frac{2\pi m e^4}{\hbar^3 E v_i k^4} \; \theta(\hbar\omega - \varepsilon_i)\,\theta(E - \hbar\omega) \tag{19}$$

where

E = energy of the incident electron,

v_i = speed of struck electron in the i^{th} level = $\sqrt{2E_i/m}$,

ε_i = "ionization energy" of struck electron,

$\theta(x)$ = (0 for $x<0$; 1 for $x>0$).

From conservation of energy and momentum the limits on the integration in Eq. (17) for the CBC model are given by

$$\hbar k_\pm = \sqrt{2m} \begin{cases} \sqrt{E_i + \hbar\omega} \pm \sqrt{E_i} \quad , & \text{for } E \geq \hbar\omega + E_i \\ \sqrt{E} \pm \sqrt{E - \hbar\omega} \quad , & \text{for } E < \hbar\omega + E_i . \end{cases} \tag{20}$$

For a given atomic level the function $\frac{d^2\sigma_i}{dk\,d(\hbar\omega)}$, Eq. (19), becomes a function also of v_i, and is averaged over a distribution of electron speeds for this level. We use here the hydrogenic speed distribution given by[8,9]

$$f(v_i) = \left(\frac{32}{\pi}\right) v_i^2 \, v_{oi}^5 \, (v_i^2 + v_{oi}^2)^{-4} \tag{21}$$

where v_{oi} is the mean speed of electrons in the i^{th} level and is set equal to $\sqrt{2\varepsilon_i/m}$. The GOS, Eq. (18), and DIMFP, Eq. (17), averaged over this speed distribution for the i^{th} level are defined by

$$\frac{df_i^{AV}(k,\omega)}{d(\hbar\omega)} = \int_0^\infty dv_i \, f(v_i) \, \frac{df_i(k,\omega)}{d(\hbar\omega)}, \tag{22}$$

$$\tau_i^{AV}(E,\hbar\omega) = \int_0^\infty dv_i \, f(v_i) \, \tau_i(E,\hbar\omega). \tag{23}$$

The results of these integrations are[8,9]

$$\frac{df_i^{AV}(\eta,x)}{dx} = \frac{2^8}{3\pi} \, \frac{x\eta^3}{[(x-\eta)^2+4\eta^2]^3} \tag{24}$$

$$\tau_i^{AV}(\beta,x) = \frac{A_i}{3\pi a_o} \, \frac{\theta(x-1)}{\beta x^3} \left[(3x+4)\left(\tan^{-1}y + \frac{y}{1+y^2}\right) + \frac{2y(x-4)}{(1+y^2)^2}\right], \tag{25}$$

where the variables are defined by

$$\eta = \hbar k/\sqrt{2m\varepsilon_i} \ ,$$

$$\beta = E/\varepsilon_i \ ,$$

$$x = \hbar\omega/\varepsilon_i \ ,$$

$$y = \sqrt{\beta - x} \ ,$$

$$A_i = 8\pi a_o^3 n_i (R/\varepsilon_i)^2 \ ,$$

$$a_o = \hbar^2/me^2 = 0.529\text{Å} \ ,$$

$$R = e^2/2a_o = 13.6 \text{ eV}.$$

It is well known that the CBC cross sections do not satisfy the fundamental Bethe sum rule[9]. It is straightforward to show that if

$$f_i^{AV}(\eta) = \int_1^\infty \frac{df_i^{AV}(\eta,x)\,dx}{dx} \tag{26}$$

then from Eq. (24), $f_i^{AV}(\eta)\to 1$ as $\eta\to\infty$ as it should, but that $f_i^{AV}(\eta)\to o$ as $\eta\to o$. To remedy this deficiency in an approximate way we may add oscillator strength at energy losses around ε_i with k-dependent amplitude $1-f_i^{AV}(k)$. We approximate the true GOS of a given shell by

$$\frac{df_i(k,\omega)}{d\omega} = \frac{df_i(o,\omega)}{d\omega}\left[1-f_i^{AV}(k)\right] + \frac{df_i^{AV}(k,\omega)}{d\omega} \ , \tag{27}$$

where $\dfrac{df_i(o,\omega)}{d\omega}$ is the known optical oscillator strength. That is, we have used an interpolation scheme for the GOS which reduces to the optical oscillator strength for small momentum transfers and which goes over into the CBC GOS values for large momentum transfer.

We have used a form

$$\frac{df_i(o,\omega)}{d\omega} = C \frac{(\omega-\varepsilon_i)}{(a+\omega)^{\alpha+1}} \tag{28}$$

to represent the optical oscillator strength of a given shell and adjusted parameters a and α so that the total stopping power including that of the valence band agrees with the Bethe formula in the high energy region. Parameters chosen for inner shells of both Ge and GaAs are $\alpha = 3.5$ and $a = 0.165$.

From the τ_i, obtained from Eq. (17), (18), and (21), we calculate an exchange corrected DIMFP from Eq. (35) of Section V. Then using Eqs. (36)-(38) of Section V, we calculate exchange corrected inverse mean free path, stopping power, and mean square energy loss which may be written in the form

$$\mu_i(\beta) = \frac{4n_i a_o^2}{(\varepsilon_i/R)^2} F(\beta), \tag{29}$$

$$S_i(\beta) = \frac{4\varepsilon_i n_i a_o^2}{(\varepsilon_i/R)^2} G(\beta), \tag{30}$$

$$\Omega_i^2(\beta) = \frac{4\varepsilon_i^2 n_i a_o^2}{(\varepsilon_i/R)^2} H(\beta). \tag{31}$$

The universal functions F, G, and H defined by these equations are tabulated in Table 3 as a function of β.

V. EXCHANGE CORRECTED DIMFP's AND FORMULAE FOR THE TABULATIONS

We have included the effect of electron exchange in our calculations in a simple manner based on the form of the Mott formula (nonrelativistic Møller formula) for scattering of an incident electron with a free electron. The cross section for finding a scattered electron with energy W per unit energy interval is given by[11]

$$\frac{d\Phi}{dW} = \frac{\pi e^4}{E}\left[\frac{1}{W^2} + \frac{1}{(E-W)^2} - \frac{1}{W(E-W)}\right] \tag{32}$$

for an incident electron of energy E, except for energies close to W = 0 and W = E. Near W = 0 and W = E the interference term (third term on the right side of Eq. (32) is effectively zero.

The DIMFP for excitation of an electron from a particular state i may be written in the form

$$\tau_i(E,\hbar\omega) = \frac{1}{E} F_i(E,\hbar\omega). \tag{33}$$

If we assume that the width of the level from which an electron is excited is quite narrow, we obtain from Eq. (33) the DIMFP for production of a secondary electron with energy E_s as

$$\tau_i^s(E,E_s) = \frac{1}{E} F_i(E,E_i^B+E_s) \tag{34}$$

where E_i^B is the binding energy of the i^{th} level (a positive quantity). The exchange corrected DIMFP is taken as

$$\tau_i^{exc}(E,\hbar\omega) = \frac{1}{E}\left\{F_i(E,\hbar\omega) + F_i(E,E+E_i^B-\hbar\omega) - \left[1-\sqrt{E_i^B/E}\right]\left[F_i(E,\hbar\omega)F_i(E,E+E_i^B-\hbar\omega)\right]^{\frac{1}{2}}\right\} . \quad (35)$$

Since $E\tau_i \propto 1/(\hbar\omega)^2$ for large E and $\hbar\omega$, Eq. (35) reduces in this limit to the form given by Eq. (32). The factor $1 - \sqrt{E_i^B/E}$ reduces the contribution of the third term in Eq. (35) as $E \to E_i^B$. This form for the exchange corrected DIMFP has been used in our calculations for all the inner shells and for the valence bands (since our model assumes the width of these levels to be quite narrow).

If we now define the more energetic of the two electrons after collision to be the primary and account for exchange through Eq. (35), Eq. (3) gives the contribution to the inverse mean free path due to excitation of an electron from the i^{th} level as

$$\mu_i(E) = \int_{E_i^B}^{(E+E_i^B)/2} d(\hbar\omega)\ \tau_i^{exc}(E,\hbar\omega) . \quad (36)$$

Similarly, for the stopping power and mean square energy loss per unit path length, we have from Eq. (4) and Eq. (5)

$$S_i(E) = \int_{E_i^B}^{(E+E_i^B)/2} d(\hbar\omega)\ \hbar\omega\ \tau_i^{exc}(E,\hbar\omega) \quad (37)$$

and

$$\Omega_i^2(E) = \int_{E_i^B}^{(E+E_i^B)/2} d(\hbar\omega)(\hbar\omega)^2 \, \tau_i^{exc}(E,\hbar\omega). \tag{38}$$

For the remaining calculations we form the sums

$$S_{exc}(E) = \sum_i S_i(E) \tag{39}$$

and

$$\Omega_{exc}^2(E) = \sum_i \Omega_i^2(E) \tag{40}$$

where the index i includes the terms appropriate for a given solid, including exchange corrections as indicated above. The csda range is calculated from

$$R_{(10)}(E) = \int_{10eV}^{E} dE'/S_{exc}(E') \tag{41}$$

corresponding to an electron slowing down in a <u>continuous</u> manner from an energy E to 10 eV. The mean square fluctuation in the csda range based on Eq. (7) is calculated as

$$[\Delta R_{(10)}]_{AV}^2 = \int_{10\ eV}^{E} dE' \, \Omega_{exc}^2(E')/[S_{exc}(E')]^3. \tag{42}$$

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VII. GERMANIUM: EXPLANATION OF TABLES

General Notes

1. Electron energies are measured from the bottom of the conduction band.

2. The density of solid Ge is taken to be $5.30 g/cm^3$.

3. The computer-printed units are translated as:

EV.....	eV	A.....	$\mathring{A}$
EV2.....	$(eV)^2$	A-1.....	$\mathring{A}^{-1}$
G/CM3.....	g/cm^3	A2.....	$\mathring{A}^2$

4. The numerical printout is in the form, e.g.,

   2.8D-01 ≡ 2.8×10^{-1}

TABLE 1A —— INVERSE MEAN FREE PATH OF ELECTRONS IN GERMANIUM

INNER SH.	Inner shell contribution to inverse mean free path
VALENCE	Valence band contribution to inverse mean free path
TOTAL	μ - total inverse mean free path = sum of inner shell and valence band contributions

TABLE 1B —— STOPPING POWER OF GERMANIUM FOR ELECTRONS

INNER SH.	Inner shell contribution to stopping power
VALENCE	Valence band contribution to stopping power
TOTAL	S - total stopping power = sum of inner shell and valence band contributions

TABLE 1C — CSDA RANGE AND STRAGGLING OF ELECTRONS IN GERMANIUM

CSDA RANGE (E - 10 EV)	$R_{(10)}$	- the range of an electron in the continuous-slowing-down approximation in going from an energy E to 10 eV.
MEAN SQ. EN. LOSS	ω^2_{exc}	- the mean square fluctuation in the energy loss per unit path length
MEAN SQ. RANGE FL.	$[\Delta R_{(10)}]^2_{AV}$	- the mean square fluctuation in the range about the mean csda range $R_{(10)}$
RELATIVE RANGE STRAGGLING	$\{[\Delta R_{(10)}]^2_{AV}\}^{1/2}/R_{(10)}$	

TABLE 1A-INVERSE MEAN FREE PATH OF ELECTRONS IN GERMANIUM

ELECTRON ENERGY EV	INVERSE MFP IN UNITS OF A-1		
	INNER SH.	VALENCE	TOTAL
1.00D 00	0.0	0.0	0.0
1.50D 00	0.0	0.0	0.0
2.00D 00	0.0	1.884D-03	1.884D-03
2.50D 00	0.0	2.713D-03	2.713D-03
3.00D 00	0.0	3.704D-03	3.704D-03
3.50D 00	0.0	4.841D-03	4.841D-03
4.00D 00	0.0	6.031D-03	6.031D-03
4.50D 00	0.0	7.312D-03	7.312D-03
5.00D 00	0.0	8.786D-03	8.786D-03
5.50D 00	0.0	1.021D-02	1.021D-02
6.00D 00	0.0	1.183D-02	1.183D-02
6.50D 00	0.0	1.355D-02	1.355D-02
7.00D 00	0.0	1.528D-02	1.528D-02
7.50D 00	0.0	1.732D-02	1.732D-02
8.00D 00	0.0	1.991D-02	1.991D-02
8.50D 00	0.0	2.229D-02	2.229D-02
9.00D 00	0.0	2.436D-02	2.436D-02
9.50D 00	0.0	2.642D-02	2.642D-02
1.00D 01	0.0	2.854D-02	2.854D-02
1.50D 01	0.0	5.360D-02	5.360D-02
2.00D 01	0.0	8.552D-02	8.552D-02
2.50D 01	0.0	1.269D-01	1.269D-01
3.00D 01	0.0	1.601D-01	1.601D-01
3.50D 01	0.0	1.798D-01	1.798D-01
4.00D 01	4.115D-03	1.923D-01	1.964D-01
4.50D 01	9.965D-03	2.028D-01	2.128D-01
5.00D 01	1.852D-02	2.098D-01	2.283D-01
5.50D 01	2.820D-02	2.134D-01	2.416D-01
6.00D 01	3.549D-02	2.143D-01	2.497D-01
6.50D 01	4.201D-02	2.136D-01	2.556D-01
7.00D 01	4.698D-02	2.115D-01	2.585D-01
7.50D 01	5.090D-02	2.086D-01	2.595D-01
8.00D 01	5.395D-02	2.054D-01	2.593D-01
8.50D 01	5.612D-02	2.016D-01	2.577D-01
9.00D 01	5.784D-02	1.977D-01	2.555D-01
9.50D 01	5.916D-02	1.938D-01	2.529D-01
1.00D 02	6.004D-02	1.899D-01	2.499D-01
1.50D 02	5.956D-02	1.551D-01	2.146D-01
2.00D 02	5.544D-02	1.303D-01	1.857D-01
2.50D 02	5.103D-02	1.125D-01	1.635D-01
3.00D 02	4.697D-02	9.915D-02	1.461D-01
3.50D 02	4.340D-02	8.883D-02	1.322D-01
4.00D 02	4.030D-02	8.059D-02	1.209D-01
4.50D 02	3.760D-02	7.383D-02	1.114D-01
5.00D 02	3.525D-02	6.820D-02	1.035D-01
5.50D 02	3.319D-02	6.342D-02	9.661D-02
6.00D 02	3.136D-02	5.930D-02	9.067D-02
6.50D 02	2.974D-02	5.573D-02	8.547D-02
7.00D 02	2.828D-02	5.260D-02	8.088D-02
7.50D 02	2.698D-02	4.982D-02	7.680D-02
8.00D 02	2.579D-02	4.735D-02	7.314D-02
8.50D 02	2.471D-02	4.512D-02	6.984D-02
9.00D 02	2.373D-02	4.311D-02	6.684D-02
9.50D 02	2.283D-02	4.128D-02	6.411D-02
1.00D 03	2.199D-02	3.961D-02	6.161D-02
1.50D 03	1.626D-02	2.848D-02	4.474D-02
2.00D 03	1.304D-02	2.244D-02	3.547D-02
2.50D 03	1.094D-02	1.861D-02	2.955D-02
3.00D 03	9.458D-03	1.596D-02	2.541D-02
3.50D 03	8.351D-03	1.400D-02	2.235D-02
4.00D 03	7.490D-03	1.249D-02	1.998D-02
4.50D 03	6.800D-03	1.129D-02	1.809D-02
5.00D 03	6.233D-03	1.032D-02	1.655D-02
5.50D 03	5.759D-03	9.505D-03	1.526D-02
6.00D 03	5.356D-03	8.817D-03	1.417D-02
6.50D 03	5.009D-03	8.228D-03	1.324D-02
7.00D 03	4.707D-03	7.716D-03	1.242D-02
7.50D 03	4.441D-03	7.258D-03	1.171D-02
8.00D 03	4.206D-03	6.872D-03	1.108D-02
8.50D 03	3.995D-03	6.519D-03	1.051D-02
9.00D 03	3.806D-03	6.202D-03	1.001D-02
9.50D 03	3.635D-03	5.917D-03	9.552D-03
1.00D 04	3.480D-03	5.658D-03	9.138D-03

TABLE 18-STOPPING POWER OF GERMANIUM FOR ELECTRONS

ELECTRON ENERGY EV	STOPPING POWER IN UNITS OF EV/A		
	INNER SH.	VALENCE	TOTAL
1.00D 00	0.0	0.0	0.0
1.50D 00	0.0	0.0	0.0
2.00D 00	0.0	3.761D-03	3.761D-03
2.50D 00	0.0	5.415D-03	5.415D-03
3.00D 00	0.0	8.401D-03	8.401D-03
3.50D 00	0.0	1.141D-02	1.141D-02
4.00D 00	0.0	1.563D-02	1.563D-02
4.50D 00	0.0	2.026D-02	2.026D-02
5.00D 00	0.0	2.617D-02	2.617D-02
5.50D 00	0.0	3.225D-02	3.225D-02
6.00D 00	0.0	3.943D-02	3.943D-02
6.50D 00	0.0	4.733D-02	4.733D-02
7.00D 00	0.0	5.651D-02	5.651D-02
7.50D 00	0.0	6.641D-02	6.641D-02
8.00D 00	0.0	7.810D-02	7.810D-02
8.50D 00	0.0	9.111D-02	9.111D-02
9.00D 00	0.0	1.060D-01	1.060D-01
9.50D 00	0.0	1.174D-01	1.174D-01
1.00D 01	0.0	1.298D-01	1.298D-01
1.50D 01	0.0	3.090D-01	3.090D-01
2.00D 01	0.0	6.230D-01	6.230D-01
2.50D 01	0.0	1.150D 00	1.150D 00
3.00D 01	0.0	1.796D 00	1.796D 00
3.50D 01	0.0	2.398D 00	2.398D 00
4.00D 01	1.623D-01	2.901D 00	3.063D 00
4.50D 01	4.060D-01	3.295D 00	3.701D 00
5.00D 01	7.773D-01	3.593D 00	4.370D 00
5.50D 01	1.217D 00	3.799D 00	5.016D 00
6.00D 01	1.572D 00	3.912D 00	5.484D 00
6.50D 01	1.905D 00	3.982D 00	5.888D 00
7.00D 01	2.179D 00	4.011D 00	6.189D 00
7.50D 01	2.410D 00	4.009D 00	6.419D 00
8.00D 01	2.604D 00	3.993D 00	6.598D 00
8.50D 01	2.758D 00	3.960D 00	6.718D 00
9.00D 01	2.891D 00	3.918D 00	6.809D 00
9.50D 01	3.004D 00	3.871D 00	6.875D 00
1.00D 02	3.094D 00	3.822D 00	6.916D 00
1.50D 02	3.483D 00	3.271D 00	6.754D 00
2.00D 02	3.614D 00	2.821D 00	6.435D 00
2.50D 02	3.611D 00	2.480D 00	6.091D 00
3.00D 02	3.532D 00	2.216D 00	5.748D 00
3.50D 02	3.421D 00	2.008D 00	5.428D 00
4.00D 02	3.297D 00	1.838D 00	5.136D 00
4.50D 02	3.173D 00	1.697D 00	4.871D 00
5.00D 02	3.053D 00	1.579D 00	4.632D 00
5.50D 02	2.939D 00	1.477D 00	4.416D 00
6.00D 02	2.831D 00	1.389D 00	4.220D 00
6.50D 02	2.731D 00	1.311D 00	4.042D 00
7.00D 02	2.637D 00	1.243D 00	3.880D 00
7.50D 02	2.550D 00	1.182D 00	3.732D 00
8.00D 02	2.468D 00	1.128D 00	3.596D 00
8.50D 02	2.392D 00	1.078D 00	3.470D 00
9.00D 02	2.321D 00	1.034D 00	3.354D 00
9.50D 02	2.254D 00	9.926D-01	3.247D 00
1.00D 03	2.191D 00	9.551D-01	3.147D 00
1.50D 03	1.741D 00	7.010D-01	2.442D 00
2.00D 03	1.483D 00	5.598D-01	2.042D 00
2.50D 03	1.304D 00	4.689D-01	1.773D 00
3.00D 03	1.170D 00	4.051D-01	1.575D 00
3.50D 03	1.064D 00	3.576D-01	1.421D 00
4.00D 03	9.776D-01	3.208D-01	1.298D 00
4.50D 03	9.059D-01	2.913D-01	1.197D 00
5.00D 03	8.452D-01	2.671D-01	1.112D 00
5.50D 03	7.930D-01	2.469D-01	1.040D 00
6.00D 03	7.476D-01	2.298D-01	9.773D-01
6.50D 03	7.077D-01	2.150D-01	9.227D-01
7.00D 03	6.723D-01	2.021D-01	8.744D-01
7.50D 03	6.407D-01	1.908D-01	8.315D-01
8.00D 03	6.122D-01	1.808D-01	7.930D-01
8.50D 03	5.865D-01	1.718D-01	7.583D-01
9.00D 03	5.630D-01	1.638D-01	7.268D-01
9.50D 03	5.416D-01	1.565D-01	6.981D-01
1.00D 04	5.219D-01	1.499D-01	6.718D-01

TABLE 1C-CSDA RANGE AND STRAGGLING OF ELECTRONS IN GERMANIUM

ELECTRON ENERGY EV	CSDA RANGE (E - 10EV) A	MEAN SQ. EN. LOSS EV/A	MEAN SQ. RANGE FL. A2	RELATIVE RANGE STRAGGLING
1.50D 01	2.532D 01	6.121D-01	7.159D 02	1.057D 00
2.00D 01	3.686D 01	1.931D 00	9.074D 02	8.173D-01
2.50D 01	4.275D 01	4.986D 00	9.702D 02	7.286D-01
3.00D 01	4.620D 01	1.145D 01	9.967D 02	6.833D-01
3.50D 01	4.861D 01	2.199D 01	1.012D 03	6.544D-01
4.00D 01	5.045D 01	3.474D 01	1.023D 03	6.340D-01
4.50D 01	5.193D 01	5.385D 01	1.031D 03	6.183D-01
5.00D 01	5.318D 01	7.457D 01	1.038D 03	6.058D-01
5.50D 01	5.424D 01	9.954D 01	1.043D 03	5.955D-01
6.00D 01	5.519D 01	1.265D 02	1.048D 03	5.866D-01
6.50D 01	5.607D 01	1.484D 02	1.052D 03	5.786D-01
7.00D 01	5.690D 01	1.691D 02	1.056D 03	5.712D-01
7.50D 01	5.769D 01	1.867D 02	1.060D 03	5.644D-01
8.00D 01	5.846D 01	2.021D 02	1.064D 03	5.580D-01
8.50D 01	5.921D 01	2.156D 02	1.068D 03	5.519D-01
9.00D 01	5.995D 01	2.269D 02	1.072D 03	5.460D-01
9.50D 01	6.068D 01	2.370D 02	1.075D 03	5.404D-01
1.00D 02	6.140D 01	2.461D 02	1.079D 03	5.350D-01
1.50D 02	6.865D 01	2.540D 02	1.122D 03	4.880D-01
2.00D 02	7.623D 01	3.084D 02	1.181D 03	4.507D-01
2.50D 02	8.421D 01	3.567D 02	1.257D 03	4.210D-01
3.00D 02	9.266D 01	3.927D 02	1.355D 03	3.973D-01
3.50D 02	1.016D 02	4.162D 02	1.477D 03	3.782D-01
4.00D 02	1.111D 02	4.314D 02	1.626D 03	3.630D-01
4.50D 02	1.211D 02	4.408D 02	1.804D 03	3.507D-01
5.00D 02	1.316D 02	4.466D 02	2.013D 03	3.409D-01
5.50D 02	1.427D 02	4.499D 02	2.257D 03	3.330D-01
6.00D 02	1.543D 02	4.513D 02	2.538D 03	3.266D-01
6.50D 02	1.664D 02	4.517D 02	2.859D 03	3.214D-01
7.00D 02	1.790D 02	4.512D 02	3.222D 03	3.171D-01
7.50D 02	1.921D 02	4.501D 02	3.630D 03	3.136D-01
8.00D 02	2.058D 02	4.487D 02	4.086D 03	3.106D-01
8.50D 02	2.200D 02	4.469D 02	4.592D 03	3.081D-01
9.00D 02	2.346D 02	4.450D 02	5.152D 03	3.059D-01
9.50D 02	2.498D 02	4.429D 02	5.767D 03	3.040D-01
1.00D 03	2.654D 02	4.408D 02	6.441D 03	3.024D-01
1.50D 03	4.477D 02	4.386D 02	1.714D 04	2.924D-01
2.00D 03	6.728D 02	4.357D 02	3.782D 04	2.890D-01
2.50D 03	9.365D 02	4.635D 02	7.286D 04	2.882D-01
3.00D 03	1.236D 03	4.857D 02	1.263D 05	2.875D-01
3.50D 03	1.571D 03	4.999D 02	2.022D 05	2.862D-01
4.00D 03	1.940D 03	5.086D 02	3.048D 05	2.846D-01
4.50D 03	2.341D 03	5.136D 02	4.383D 05	2.828D-01
5.00D 03	2.775D 03	5.161D 02	6.071D 05	2.808D-01
5.50D 03	3.240D 03	5.172D 02	8.156D 05	2.787D-01
6.00D 03	3.736D 03	5.170D 02	1.068D 06	2.767D-01
6.50D 03	4.263D 03	5.163D 02	1.370D 06	2.746D-01
7.00D 03	4.820D 03	5.150D 02	1.726D 06	2.726D-01
7.50D 03	5.406D 03	5.135D 02	2.140D 06	2.706D-01
8.00D 03	6.022D 03	5.117D 02	2.618D 06	2.686D-01
8.50D 03	6.667D 03	5.098D 02	3.164D 06	2.668D-01
9.00D 03	7.341D 03	5.078D 02	3.784D 06	2.650D-01
9.50D 03	8.043D 03	5.057D 02	4.483D 06	2.632D-01
1.00D 04	8.774D 03	5.037D 02	5.266D 06	2.616D-01

VIII. GALLIUM ARSENIDE: EXPLANATION OF TABLES

General Notes

1. Electron energies are measured from the bottom of the conduction band.

2. The density of solid GaAs is taken to be 5.31 g/cm^3.

3. The computer-printed units are translated as:

EV.....	eV	A.....	$\mathring{A}$
EV2.....	$(eV)^2$	A-1.....	$\mathring{A}^{-1}$
G/CM3.....	g/cm^3	A2.....	$\mathring{A}^2$

4. The numerical printout is in the form, e.g., 2.8D-2 = 2.8×10^{-2}.

TABLE 2A —— INVERSE MEAN FREE PATH OF ELECTRON IN GALLIUM ARSENIDE

INNER SH.	Inner shell contribution to inverse mean free path
VALENCE	Valence band contribution to inverse mean free path
TOTAL	μ - total inverse mean free path = sum of inner shell and valence band contributions

TABLE 2B —— STOPPING POWER OF GALLIUM ARSENIDE FOR ELECTRONS

INNER SH.	Inner shell contribution to stopping power
VALENCE	Valence band contribution to stopping power
TOTAL	S - total stopping power = sum of inner shell and valence band contributions

TABLE 2C —— CSDA RANGE AND STRAGGLING OF ELECTRONS IN GALLIUM ARSENIDE

CSDA RANGE (E-10EV)	$R_{(10)}$	- the range of an electron in the continuous-slowing-down approximation in going from an energy E to 10 eV
MEAN SQ. EN. LOSS	Ω^2_{exc}	- the mean square fluctuation in the energy loss per unit path length
MEAN SQ. RANGE FL.	$[\Delta R_{(10)}]^2_{AV}$	- the mean square fluctuation in the range about the mean csda range $R_{(10)}$
RELATIVE RANGE STRAGGLING	$\{[\Delta R_{(10)}]^2_{AV}\}^{1/2}/R_{(10)}$	

TABLE 2A-INVERSE MEAN FREE PATH OF ELECTRONS IN GALLIUM ARSENIDE

ELECTRON ENERGY EV	INVERSE MFP IN UNITS OF A-1		
	INNER SH.	VALENCE	TOTAL
1.000 00	0.0	0.0	0.0
1.500 00	0.0	0.0	0.0
2.000 00	0.0	3.107D-03	3.107D-03
2.500 00	0.0	4.362D-03	4.362D-03
3.000 00	0.0	5.741D-03	5.741D-03
3.500 00	0.0	7.229D-03	7.229D-03
4.000 00	0.0	8.815D-03	8.815D-03
4.500 00	0.0	1.049D-02	1.049D-02
5.000 00	0.0	1.224D-02	1.224D-02
5.500 00	0.0	1.407D-02	1.407D-02
6.000 00	0.0	1.597D-02	1.597D-02
6.500 00	0.0	1.794D-02	1.794D-02
7.000 00	0.0	1.996D-02	1.996D-02
7.500 00	0.0	2.204D-02	2.204D-02
8.000 00	0.0	2.418D-02	2.418D-02
8.500 00	0.0	2.637D-02	2.637D-02
9.000 00	0.0	2.861D-02	2.861D-02
9.500 00	0.0	3.089D-02	3.089D-02
1.000 01	0.0	3.323D-02	3.323D-02
1.500 01	0.0	5.866D-02	5.866D-02
2.000 01	0.0	8.718D-02	8.718D-02
2.500 01	0.0	1.193D-01	1.193D-01
3.000 01	6.722D-03	1.470D-01	1.537D-01
3.500 01	1.791D-02	1.662D-01	1.841D-01
4.000 01	3.100D-02	1.793D-01	2.103D-01
4.500 01	4.088D-02	1.892D-01	2.301D-01
5.000 01	4.815D-02	1.958D-01	2.440D-01
5.500 01	5.499D-02	1.995D-01	2.545D-01
6.000 01	5.969D-02	2.007D-01	2.604D-01
6.500 01	6.387D-02	2.005D-01	2.643D-01
7.000 01	6.747D-02	1.990D-01	2.664D-01
7.500 01	7.008D-02	1.966D-01	2.667D-01
8.000 01	7.197D-02	1.938D-01	2.658D-01
8.500 01	7.336D-02	1.905D-01	2.639D-01
9.000 01	7.425D-02	1.871D-01	2.613D-01
9.500 01	7.472D-02	1.835D-01	2.583D-01
1.000 02	7.493D-02	1.800D-01	2.550D-01
1.500 02	7.084D-02	1.479D-01	2.187D-01
2.000 02	6.452D-02	1.246D-01	1.891D-01
2.500 02	5.868D-02	1.077D-01	1.664D-01
3.000 02	5.362D-02	9.498D-02	1.486D-01
3.500 02	4.930D-02	8.512D-02	1.344D-01
4.000 02	4.561D-02	7.724D-02	1.229D-01
4.500 02	4.244D-02	7.076D-02	1.132D-01
5.000 02	3.970D-02	6.536D-02	1.051D-01
5.500 02	3.730D-02	6.078D-02	9.809D-02
6.000 02	3.519D-02	5.684D-02	9.203D-02
6.500 02	3.333D-02	5.341D-02	8.674D-02
7.000 02	3.166D-02	5.040D-02	8.206D-02
7.500 02	3.017D-02	4.774D-02	7.791D-02
8.000 02	2.882D-02	4.537D-02	7.418D-02
8.500 02	2.759D-02	4.323D-02	7.082D-02
9.000 02	2.647D-02	4.129D-02	6.776D-02
9.500 02	2.545D-02	3.954D-02	6.498D-02
1.000 03	2.450D-02	3.794D-02	6.244D-02
1.500 03	1.805D-02	2.725D-02	4.530D-02
2.000 03	1.443D-02	2.146D-02	3.589D-02
2.500 03	1.209D-02	1.780D-02	2.988D-02
3.000 03	1.044D-02	1.525D-02	2.569D-02
3.500 03	9.209D-03	1.338D-02	2.259D-02
4.000 03	8.254D-03	1.194D-02	2.019D-02
4.500 03	7.489D-03	1.079D-02	1.828D-02
5.000 03	6.861D-03	9.856D-03	1.672D-02
5.500 03	6.337D-03	9.079D-03	1.542D-02
6.000 03	5.891D-03	8.421D-03	1.431D-02
6.500 03	5.508D-03	7.857D-03	1.337D-02
7.000 03	5.174D-03	7.368D-03	1.254D-02
7.500 03	4.881D-03	6.940D-03	1.182D-02
8.000 03	4.621D-03	6.561D-03	1.118D-02
8.500 03	4.389D-03	6.223D-03	1.061D-02
9.000 03	4.180D-03	5.920D-03	1.010D-02
9.500 03	3.992D-03	5.647D-03	9.639D-03
1.000 04	3.820D-03	5.400D-03	9.220D-03

TABLE 23-STOPPING POWER OF GALLIUM ARSENIDE FOR ELECTRONS

ELECTRON ENERGY EV	STOPPING POWER IN UNITS OF EV/A		
	INNER SH.	VALENCE	TOTAL
1.00D 00	0.0	0.0	0.0
1.50D 00	0.0	0.0	0.0
2.00D 00	0.0	1.001D-02	1.001D-02
2.50D 00	0.0	1.381D-02	1.381D-02
3.00D 00	0.0	1.876D-02	1.876D-02
3.50D 00	0.0	2.406D-02	2.406D-02
4.00D 00	0.0	3.132D-02	3.132D-02
4.50D 00	0.0	3.858D-02	3.858D-02
5.00D 00	0.0	4.659D-02	4.659D-02
5.50D 00	0.0	5.450D-02	5.450D-02
6.00D 00	0.0	6.311D-02	6.311D-02
6.50D 00	0.0	7.243D-02	7.243D-02
7.00D 00	0.0	8.249D-02	8.249D-02
7.50D 00	0.0	9.329D-02	9.329D-02
8.00D 00	0.0	1.049D-01	1.049D-01
8.50D 00	0.0	1.173D-01	1.173D-01
9.00D 00	0.0	1.305D-01	1.305D-01
9.50D 00	0.0	1.445D-01	1.445D-01
1.00D 01	0.0	1.594D-01	1.594D-01
1.50D 01	0.0	3.602D-01	3.602D-01
2.00D 01	0.0	6.705D-01	6.705D-01
2.50D 01	0.0	1.124D 00	1.124D 00
3.00D 01	1.903D-01	1.672D 00	1.862D 00
3.50D 01	5.295D-01	2.209D 00	2.738D 00
4.00D 01	9.526D-01	2.678D 00	3.631D 00
4.50D 01	1.301D 00	3.055D 00	4.356D 00
5.00D 01	1.582D 00	3.346D 00	4.928D 00
5.50D 01	1.889D 00	3.556D 00	5.445D 00
6.00D 01	2.129D 00	3.683D 00	5.812D 00
6.50D 01	2.365D 00	3.768D 00	6.132D 00
7.00D 01	2.589D 00	3.811D 00	6.400D 00
7.50D 01	2.776D 00	3.825D 00	6.601D 00
8.00D 01	2.931D 00	3.823D 00	6.754D 00
8.50D 01	3.065D 00	3.802D 00	6.867D 00
9.00D 01	3.174D 00	3.771D 00	6.945D 00
9.50D 01	3.261D 00	3.735D 00	6.996D 00
1.00D 02	3.333D 00	3.694D 00	7.027D 00
1.50D 02	3.680D 00	3.198D 00	6.879D 00
2.00D 02	3.761D 00	2.772D 00	6.533D 00
2.50D 02	3.727D 00	2.443D 00	6.170D 00
3.00D 02	3.631D 00	2.187D 00	5.818D 00
3.50D 02	3.507D 00	1.983D 00	5.491D 00
4.00D 02	3.375D 00	1.817D 00	5.193D 00
4.50D 02	3.244D 00	1.679D 00	4.923D 00
5.00D 02	3.118D 00	1.562D 00	4.680D 00
5.50D 02	2.998D 00	1.462D 00	4.460D 00
6.00D 02	2.887D 00	1.375D 00	4.262D 00
6.50D 02	2.783D 00	1.299D 00	4.081D 00
7.00D 02	2.686D 00	1.231D 00	3.917D 00
7.50D 02	2.596D 00	1.171D 00	3.767D 00
8.00D 02	2.512D 00	1.117D 00	3.629D 00
8.50D 02	2.434D 00	1.069D 00	3.502D 00
9.00D 02	2.360D 00	1.024D 00	3.385D 00
9.50D 02	2.292D 00	9.838D-01	3.276D 00
1.00D 03	2.228D 00	9.467D-01	3.174D 00
1.50D 03	1.769D 00	6.952D-01	2.464D 00
2.00D 03	1.504D 00	5.553D-01	2.059D 00
2.50D 03	1.322D 00	4.652D-01	1.787D 00
3.00D 03	1.185D 00	4.020D-01	1.587D 00
3.50D 03	1.077D 00	3.549D-01	1.432D 00
4.00D 03	9.894D-01	3.184D-01	1.308D 00
4.50D 03	9.166D-01	2.891D-01	1.206D 00
5.00D 03	8.550D-01	2.651D-01	1.120D 00
5.50D 03	8.021D-01	2.451D-01	1.047D 00
6.00D 03	7.560D-01	2.281D-01	9.841D-01
6.50D 03	7.156D-01	2.134D-01	9.290D-01
7.00D 03	6.797D-01	2.006D-01	8.804D-01
7.50D 03	6.477D-01	1.894D-01	8.371D-01
8.00D 03	6.189D-01	1.795D-01	7.983D-01
8.50D 03	5.928D-01	1.706D-01	7.634D-01
9.00D 03	5.691D-01	1.626D-01	7.316D-01
9.50D 03	5.474D-01	1.554D-01	7.027D-01
1.00D 04	5.275D-01	1.488D-01	6.762D-01

TABLE 2C-CSDA RANGE AND STRAGGLING OF ELECTRONS IN GALLIUM ARSENIDE

ELECTRON ENERGY EV	CSDA RANGE (E - 10EV) A	MEAN SQ. EN. LOSS EV/A	MEAN SQ. RANGE FL. A2	RELATIVE RANGE STRAGGLING
1.500 01	2.100D 01	7.891D-01	5.153D 02	1.081D 00
2.000 01	3.123D 01	2.367D 00	6.724D 02	8.304D-01
2.500 01	3.705D 01	5.599D 00	7.348D 02	7.317D-01
3.000 01	4.050D 01	1.156D 01	7.636D 02	6.824D-01
3.500 01	4.270D 01	2.612D 01	7.789D 02	6.536D-01
4.000 01	4.428D 01	4.769D 01	7.883D 02	6.341D-01
4.500 01	4.553D 01	7.304D 01	7.949D 02	6.192D-01
5.000 01	4.561D 01	9.558D 01	8.002D 02	6.069D-01
5.500 01	4.757D 01	1.152D 02	8.046D 02	5.963D-01
6.000 01	4.846D 01	1.362D 02	8.087D 02	5.869D-01
6.500 01	4.929D 01	1.533D 02	8.125D 02	5.782D-01
7.000 01	5.009D 01	1.702D 02	8.161D 02	5.703D-01
7.500 01	5.086D 01	1.863D 02	8.196D 02	5.629D-01
8.000 01	5.161D 01	2.006D 02	8.231D 02	5.559D-01
8.500 01	5.234D 01	2.131D 02	8.265D 02	5.493D-01
9.000 01	5.307D 01	2.244D 02	8.300D 02	5.429D-01
9.500 01	5.378D 01	2.343D 02	8.335D 02	5.368D-01
1.000 02	5.450D 01	2.429D 02	8.371D 02	5.309D-01
1.500 02	6.163D 01	2.506D 02	8.783D 02	4.808D-01
2.000 02	6.908D 01	3.102D 02	9.338D 02	4.423D-01
2.500 02	7.696D 01	3.571D 02	1.007D 03	4.124D-01
3.000 02	8.531D 01	3.921D 02	1.102D 03	3.891D-01
3.500 02	9.416D 01	4.159D 02	1.219D 03	3.709D-01
4.000 02	1.035D 02	4.314D 02	1.363D 03	3.566D-01
4.500 02	1.134D 02	4.412D 02	1.535D 03	3.455D-01
5.000 02	1.238D 02	4.471D 02	1.739D 03	3.367D-01
5.500 02	1.348D 02	4.506D 02	1.976D 03	3.298D-01
6.000 02	1.463D 02	4.524D 02	2.249D 03	3.243D-01
6.500 02	1.582D 02	4.528D 02	2.562D 03	3.198D-01
7.000 02	1.708D 02	4.525D 02	2.916D 03	3.162D-01
7.500 02	1.838D 02	4.516D 02	3.314D 03	3.132D-01
8.000 02	1.973D 02	4.502D 02	3.759D 03	3.107D-01
8.500 02	2.113D 02	4.486D 02	4.253D 03	3.086D-01
9.000 02	2.259D 02	4.467D 02	4.800D 03	3.068D-01
9.500 02	2.409D 02	4.447D 02	5.401D 03	3.051D-01
1.000 03	2.564D 02	4.427D 02	6.060D 03	3.036D-01
1.500 03	4.370D 02	4.406D 02	1.655D 04	2.944D-01
2.000 03	6.603D 02	4.399D 02	3.687D 04	2.908D-01
2.500 03	9.218D 02	4.663D 02	7.128D 04	2.896D-01
3.000 03	1.219D 03	4.884D 02	1.238D 05	2.885D-01
3.500 03	1.552D 03	5.025D 02	1.985D 05	2.871D-01
4.000 03	1.918D 03	5.114D 02	2.994D 05	2.854D-01
4.500 03	2.316D 03	5.165D 02	4.308D 05	2.834D-01
5.000 03	2.747D 03	5.192D 02	5.970D 05	2.813D-01
5.500 03	3.209D 03	5.201D 02	8.024D 05	2.792D-01
6.000 03	3.701D 03	5.201D 02	1.051D 06	2.770D-01
6.500 03	4.225D 03	5.193D 02	1.349D 06	2.749D-01
7.000 03	4.778D 03	5.181D 02	1.699D 06	2.728D-01
7.500 03	5.360D 03	5.166D 02	2.108D 06	2.708D-01
8.000 03	5.972D 03	5.148D 02	2.579D 06	2.689D-01
8.500 03	6.613D 03	5.129D 02	3.117D 06	2.670D-01
9.000 03	7.282D 03	5.109D 02	3.729D 06	2.652D-01
9.500 03	7.980D 03	5.088D 02	4.418D 06	2.634D-01
1.000 04	8.705D 03	5.068D 02	5.191D 06	2.617D-01

TABLE 3-UNIVERSAL FUNCTIONS EMPLOYED IN THE EVALUATION OF INNER SHELL CONTRIBUTIONS TO INVERSE MEAN FREE PATH, STOPPING POWER, AND MEAN SQUARE ENERGY LOSS (SEE DEFINITIONS AND DETAILS IN SECTION IV)

BETA	F	G	H
1.20D 00	2.279D-01	2.393D-01	2.516D-01
1.40D 00	4.803D-01	5.273D-01	5.806D-01
1.70D 00	7.497D-01	8.722D-01	1.022D 00
2.00D 00	9.054D-01	1.106D 00	1.370D 00
2.50D 00	1.017D 00	1.326D 00	1.776D 00
3.00D 00	1.037D 00	1.424D 00	2.034D 00
3.50D 00	1.019D 00	1.458D 00	2.202D 00
4.00D 00	9.858D-01	1.459D 00	2.313D 00
5.00D 00	9.077D-01	1.416D 00	2.435D 00
6.00D 00	8.331D-01	1.351D 00	2.485D 00
7.00D 00	7.677D-01	1.284D 00	2.500D 00
8.00D 00	7.113D-01	1.220D 00	2.496D 00
9.00D 00	6.626D-01	1.160D 00	2.483D 00
1.00D 01	6.205D-01	1.106D 00	2.464D 00
1.30D 01	5.224D-01	9.702D-01	2.396D 00
1.60D 01	4.527D-01	8.661D-01	2.328D 00
2.00D 01	3.858D-01	7.604D-01	2.246D 00
2.50D 01	3.272D-01	6.628D-01	2.162D 00
3.00D 01	2.850D-01	5.897D-01	2.093D 00
4.00D 01	2.280D-01	4.867D-01	1.987D 00
5.00D 01	1.910D-01	4.171D-01	1.911D 00
6.00D 01	1.650D-01	3.665D-01	1.852D 00
7.00D 01	1.455D-01	3.279D-01	1.806D 00
8.00D 01	1.304D-01	2.973D-01	1.768D 00
1.00D 02	1.084D-01	2.518D-01	1.710D 00
1.30D 02	8.703D-02	2.063D-01	1.650D 00
1.60D 02	7.302D-02	1.757D-01	1.608D 00
2.00D 02	6.037D-02	1.476D-01	1.568D 00
2.50D 02	4.985D-02	1.237D-01	1.533D 00
3.00D 02	4.259D-02	1.069D-01	1.508D 00
4.00D 02	3.318D-02	8.465D-02	1.474D 00
5.00D 02	2.730D-02	7.052D-02	1.452D 00